METHOD FOR PREDICTIVE MAINTENANCE OF AN OPERATING COMPONENT OF AN AUTOMATIC MACHINE

TECHNICAL FIELD

The present invention relates to a method for predictive maintenance of an operating component of an automatic machine.

The present invention may be used to advantage on automatic machines employed in the tobacco industry, to which the following description refers purely by way of example.

BACKGROUND ART

An automatic machine comprises a number of operating components (e.g. bearings, fans, drives, motors), each of which performs a given function and is subject to malfunctions which frequently require stopping the machine to adjust or replace the component. Machine stoppages mean production hold-ups and, therefore, reduced profit on the part of the manufacturer.

To reduce the cost of production hold-ups, it is

common practice to perform routine maintenance, and in particular to adjust or replace each operating component at given intervals determined experimentally. Particularly in the case of complex automatic machines such as those used in the tobacco industry, however, the above method has been found to result in two extreme situations, depending on the selected maintenance intervals: high average breakdown frequency, thus resulting in increased cost through loss of production; or excessively frequent maintenance, thus resulting in increased maintenance cost.

Determining the right maintenance interval has always been difficult, on account of dispersion and drift in the construction and operating characteristics of each operating component. Also, breakdown frequency has been found to depend closely on the working environment (e.g. temperature or humidity) and on the type of product manufactured (in particular, the type of material used).

US 6330525 discloses a method for diagnosing a pump system according to which one or more measured values are acquired. A defect can be identified as a function of the comparison of a single measured value with an original reference value.

The method disclosed in US 6330525 has several drawbacks: *inter alia* such a method cannot determine complex defects (*i.e.* defects which cannot be determined

on the basis of one measurement) and has a relatively low reliability, since a wrong defect (*i.e.* something which is not really responsible for the malfunctioning) is relatively often identified.

DISCLOSURE OF INVENTION

It is an object of the present invention to provide a method for predicting maintenance of an operating component of an automatic machine, designed to eliminate or reduce the aforementioned drawbacks, and which, in particular, is cheap and easy to implement.

According to the present invention, there is provided a method for predicting maintenance of an operating component of an automatic machine, as claimed in Claim 1 and, preferably, in any one of the following Claims depending directly or indirectly on Claim 1.

BRIEF DESCRIPTION OF THE DRAWINGS

A number of non-limiting embodiments of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a schematic, partly sectioned, plan view, with parts removed for clarity, of a number of operating components of an automatic machine, to which a predictive maintenance method in accordance with the present invention is applied;

Figure 2 shows a section along line II-II of part of an operating component in Figure 1;

Figures 3 and 4 show diagrams of how data relative

to the operating components in Figure 1 is used in the predictive maintenance method according to the present invention;

Figure 5 shows a graph of vibration frequencies determined applying a predictive maintenance method in accordance with the present invention;

Figure 6 shows a time graph of characteristic quantities of operating components of an automatic machine to which a predictive maintenance method in accordance with the present invention is applied.

BEST MODE FOR CARRYING OUT THE INVENTION

Number 1 in Figure 1 indicates as a whole a fan unit of an automatic machine (not shown). Fan unit 1 comprises an electric motor 2, a fan 3, and a connecting unit 4 for transferring power from motor 2 to fan 3.

Connecting unit 4 comprises a drive pulley 5 integral with an output shaft 6 of motor 2; and a belt 7 looped about pulley 5 and about a pulley 8 connected integrally to a shaft 9 of fan 3. Fan 3 also comprises a number of blades 3a fitted to the opposite end of shaft 9 to pulley 8.

Unit 1 also comprises a tubular support 10 housing two radial bearings 11 and 12, which support shaft 9 for rotation about a respective longitudinal axis of rotation. As shown in Figure 2, each bearing 11, 12 comprises an outer ring 13 connected rigidly to support 10; and a number of rotating elements 14, in particular,

balls, located between outer ring 13 and shaft 9.

The outer surface of support 10 is fitted, at bearing 11, with a temperature sensor 15; and two sensors 16 oriented radially with respect to support 10 and at 90° with respect to each other, and which provide for measuring vibrational energy at different vibration frequencies. Temperature sensor 15 and both sensors 16 are connected to a control unit 17. It is important to note that the particularly arrangement of sensors 16 provides for detecting any vibration propagating radially from shaft 9.

In one embodiment, in addition to sensors 16, unit 1 also comprises a further known vibration sensor (not shown) for determining any vibration propagating longitudinally with respect to shaft 9.

In actual use, control unit 17 collects the measurements made by sensors 15 and 16, and processes them to obtain values V, which are compared with reference data to determine a specific defect and program maintenance to correct the defect, so that the machine (not shown) can be kept running as along as possible, before the defect begins to impair operation of unit 1.

In one embodiment, each measurement is processed to obtain a respective value V directly proportional to the relative measurement; each value V is compared with a respective reference data threshold value; and the

defect of unit 1 is determined as a function of the combination of the differences between each value V and the respective threshold value.

More specifically, with reference to Figure 3, to monitor bearing 11, the following characteristic quantities of bearing 11 are measured:

- temperature T of bearing 11;
- total vibrational energy G;
- vibrational energy at 6-10 kHz frequencies H;
- vibration kurtosis K;
- vibrational energy at given frequencies F typical of damage to bearing 11.

Given frequencies typical of damage to bearing 11 are intended to mean, in particular, frequencies FE typical of damage to outer ring 13; frequencies FR typical of damage to a rotating element 14; and/or frequencies FI typical of damage to shaft 9 at bearing 11.

The Figure 5 graph shows an example of the relationship between different vibration frequencies.

With reference to Figure 3, when values V of temperature T, total vibrational energy G, vibrational energy at 6-10 kHz frequencies H, and vibration kurtosis K exceed the respective threshold values, and value V of vibrational energy at given frequencies F is below the respective threshold value, a defect L is determined, caused by poor lubrication of bearing 11. When values V

of total vibrational energy G, vibrational energy at 6-10 kHz frequencies H, and vibrational kurtosis K exceed the respective threshold values, and values V of vibrational energy at given frequencies F, and temperature T are below the respective threshold values, a defect LF is determined, caused by a loose connection between bearing 11 and support 10. When values V of total vibrational energy G, vibrational energy at 6-10 kHz frequencies H, vibrational energy at given frequencies F, and vibration kurtosis K exceed the respective threshold values, and value V of temperature T is below the respective threshold value, a defect D is determined, caused by damage to bearing 11.

This is shown schematically in Figure 3, in which the symbol "•" indicates a characteristic quantity value V exceeding the respective threshold value.

In other words, a defect is identified as a function of the combination of at least two comparison: a comparison between a first measured value V and reference data and a further comparison between a second measured value V and reference data.

In a further embodiment, in addition to or instead of the above embodiment, each measurement is processed to obtain a respective value V, and the values V are combined to obtain one or more combinations of values V; each combination is compared with a respective threshold value; and the defect of bearing 11 is determined as a

function of the difference between each combination and the respective threshold value.

In alternative embodiments, as opposed to being directly proportional to the respective measurement, at least one of values V is a function of the time pattern of the respective measurement.

Control unit 17 also provides for programming maintenance of bearing 11.

In one embodiment, experimental curves are determined, each of which extrapolates the time pattern of a respective value V. In which case, maintenance is programmed as a function of the instants in which one or more experimental curves intercept respective reference curves. More specifically, maintenance may be programmed to be carried out either at the exact instant, or within a given time interval before or after the instant, in which an experimental curve intercepts the respective reference curve.

In a further embodiment, in addition to or instead of the above embodiment, values V are combined to obtain one or more combinations of values V; experimental curves of the combinations are determined, each of which extrapolates the time pattern of a respective combination of values; and maintenance is programmed as a function of the instants in which one or more experimental curves of the combinations intercept respective reference data reference curves. More

specifically, maintenance may be programmed to be carried out either at the exact instant, or within a given time interval before or after the instant, in which an experimental curve of a combination intercepts the respective reference curve.

Purely by way of example, Figure 6 shows a graph of an experimental curve, in which time is shown along the x axis, values V or combinations of values V are shown along the y axis, A indicates an experimental curve, and B a reference curve.

As shown in Figure 6, preferably, the experimental curves are linear, and each reference curves define a respective constant value.

What has been said above relative to determining defects and programming maintenance of bearing 11 also applies to fan 3. In this case, it is important to bear in mind that defects of fan 3 also comprise defects of bearing 11, which may be determined as described above.

In this case (Figure 4), the following characteristic quantities are measured:

- total vibrational energy G;
- vibrational energy at 110-1000 Hz frequencies IS;
- vibrational energy at basic machine frequency FF;
- suction pressure P of fan 3;
- temperature T of bearing 11;
- vibrational energy at 6-10 kHz frequencies H;
- vibration kurtosis K;

- vibrational energy at given frequencies F typical of damage to the bearing.

The suction pressure P of fan 3 is determined by a known sensor (not shown) fitted to fan 3 and connected to control unit 17.

It is important to note that all the characteristic quantities of bearing 11 are measured to determine a defect BF of bearing 11.

As shown in Figure 4, a defect IU caused by poor balance of fan 3, and/or a defect IW caused by wear of fan 3, can also be determined.

The proposed method therefore provides, in a relatively simple manner, for determining complex defects, i.e. defects which cannot be determined on the basis of one measurement, and at the same time for programming maintenance.

Moreover, with comparison to the known state of the art (*e.g.* US 63305259) the proposed method has a relatively high reliability as the combination of comparisons of more measurements with reference data provide a relatively deep, and then reliable, knowledge of the operating conditions of an operating component of an automatic machine.

Downtime of the machine due to component breakdown or to routine maintenance is thus reduced, and a precise indication is given of the parts actually requiring maintenance.